A1250-1
11/25/86

NOVEMBER 24, 1986

CHEMICAL & ENGINEERING

NEWS

The Changing Atmosphere

Implications for Mankind

A C&EN Special Issue

0511179C097 9 K AR6447SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 64, Number 47
CENEAR 64 (47) 1–80
ISSN 0009-2347

NOVEMBER 24, 1986

News of the Week

■ **Bhopal case legal battles between the Indian government and Union Carbide heat up again on several fronts.** **Page 4**

■ **EPA wants to collect fees from manufacturers for registering pesticides.** **Page 5**

■ **Hans Stauffer, a former president of Stauffer Chemical, is dead at 85.** **Page 6**

■ **Low-weight fuel cell produces higher power density than previous cells.** **Page 6**

■ **Cabot Corp. announces selection of new president and adoption of shareholder rights plan.** **Page 6**

The Changing Atmosphere

Global warming and depletion of stratospheric ozone confront mankind with many unknowns and put technology and social and economic policy making to the test. **Page 14**

Science of the problems

Models calculate that changes in composition of the atmosphere, caused by increasing levels of chlorofluorocarbons, carbon dioxide, and other trace gases, will lead to ozone depletion and climate warming. **Page 16**

Social, economic implications

Current estimates of the effects of ozone depletion and global warming depend on incomplete science; more socioeconomic studies need to be undertaken, but initial steps for energy conservation can be taken now. **Page 36**

Response to ozone depletion

Chlorofluorocarbon industry searches for substitute materials; U.S. industry agrees to limit global CFC production capacity but, to be effective, controls must be imposed internationally. **Page 47**

Response to global warming

Congress is stepping up its pace in dealing with the legislative aspects of climate warming; coordination needed to pull together research scattered among federal agencies. **Page 56**

Cover: Photo courtesy of National Aeronautics & Space Administration

Letters 2
Editor's Page 3

Concentrates
Business 7
Government 10
Science/Technology 12

The Departments
ACS News 66
Newscripts 80

each attempted such a calculation. By different routes, they arrived at the same number. The global costs for doubling carbon dioxide levels amount to about 3% of gross world product. Three per cent is also about the rate of economic growth worldwide. So the global costs for doubling carbon dioxide levels would "bring economic growth to a halt," Laurmann says. (Also, the simple axiom holds: The longer controls are put off, the more expensive they become.)

Getting more specific is also difficult. One of the best-studied areas is the secondary effect of global warming: sea-level rise. EPA's project manager for sea-level rise Titus says, "Nobody has estimated what it would cost to defend against a 2-meter rise in sea level. There are no nationwide or worldwide estimates." The task is complicated, Titus explains. "Is the total cost of building dikes to defend against this rise merely the cost of the loss of wetlands, or is it the cost of the dikes plus restoration of the wetlands?" The answer is important because a 1- to 2-meter rise in sea level by 2100 could destroy up to 80% of U.S. coastal wetlands.

There are place-specific estimates for a 1-meter rise or less, however. A 28-cm to 64-cm rise would cost Charleston, S.C., about $280 million to $1.07 billion in current dollars, or about 5 to 19% of economic activity, through 2025. If the sea-level rise was anticipated, the costs would drop to $160 million to $420 million. Most of this expense would come from increased storm damage. Similarly, the impact on the Galveston, Tex., area for the same sea-level rise and for the same time frame would be $115 million to $360 million, or 1.1 to 3.6% of economic activity, if unanticipated, and $80 million to $140 million if anticipated.

Studies by Woods Hole Oceanographic Institution indicate that a 1-meter rise would have devastating effects on Bangladesh. Nearly 12% of the land area, 9% of the population, and 11% of agricultural production would be affected.

Anthony E. Scoville, freelance writer and former technical consultant to the House Science & Technology Committee, suggests a way out of the greenhouse dilemma for a country like the U.S. What is needed is "to develop an economy that can better anticipate future trends, whether they are economic or environmental trends." In his yet to be released book "Climate & Capital" (Walker & Co.), he explores mechanisms that might be used to "put more foresight into our economy."

"The first thing you have to do is mobilize very large-scale savings through retirement and pension plans. That's where all the new capital is being formed in this country. Second, you have to do something about reforming the banking system so that the discount rates on short-term fund flows don't start conflicting with the longer-term investment needs, which are made on a cycle of up to 50 years." If the proper steps are taken, "This could be advantageous not only to the environmentalists but also to the people concerned about meeting technological competition," he adds.

Planetary bargain

From his studies, University of Illinois, Chicago, economist Richard F. Kosobud has concluded that it will be very difficult to get international agreement on cooperative carbon dioxide policies. Some countries may benefit from global warming, others may not.

How do developed countries respond to the concerns of the developing nations? NCAR's Schneider says, "What is needed is the concept of a global survival compromise, or a planetary bargain to quote Harlan Cleveland." Under such a regime, "the wealthy countries agree that their problem is conspicuous consumption, and the poor countries agree that their problem is population and poverty." The wealthy nations put up the resources to help the poor ones develop, beginning at the lowest strata of society. The poor nations agree to reduce population growth.

Asked how this can be implemented, Schneider answers: "Good luck!" And, he adds, "I believe the greenhouse gas problem represents the failure of the world to grapple with its single most important issue, which is global development." □

Response to ozone depletion

Easier to grapple with both politically and economically is the threatened depletion of the ozone layer 12 to 50 km above Earth's surface. In this part of the atmosphere, called the stratosphere, ozone acts to shield all living and nonliving things on Earth from most of the sun's harmful ultraviolet radiation.

Governmental efforts to stem this possible net ozone depletion have focused on man-made CFC emissions because the sources are known and controllable. For nitrous oxide, another ozone depleter, the sources are not well defined. Fertilizers and combusted fossil fuels are suspect sources, but these would be difficult to control.

Still, control of CFC emissions presents policy makers with troubling dilemmas. The effects of significant ozone depletion are likely to be large, and become apparent anywhere from decades to centuries into the future. Equally long term will be the time these effects play out. As NASA scientist Robert Watson explains, any regulatory measures now have to be taken on "a potential environmental problem that is based largely on theory."

To confound policy makers further, CFCs are useful—some would say essential—versatile, nontoxic, and nonflammable. They find wide application in refrigeration, in air conditioning, in plastic foams for insulation and packaging, as cleaning agents, and as sterilants for med-

ical supplies and devices. The Alliance for Responsible CFC Policy, an association of more than 500 CFC producers and users, has tallied U.S. CFC-related goods and services. The alliance claims they are worth more than $28 billion a year, and represent 715,000 jobs.

Because of the potential harm increased UV radiation poses to land and sea life, and to such man-made materials as plastics, some governments already have imposed bans on what they consider nonessential CFC uses. In the U.S., EPA and the Food & Drug Administration took such action in 1978, banning the use of CFCs as aerosol propellants in nearly all consumer products.

Two years later, EPA proposed to consider additional regulations on all other uses of CFCs. The agency has yet to act on this proposal, even to the extent of stating that no further regulations are needed. But under a consent agreement with the Natural Resources Defense Council (NRDC), EPA, by next May, will have to declare whether it intends to issue further regulations.

Until very recently, producers and users of CFCs argued that further regulations were uncalled for until science proves the ozone-depletion theory valid. They reasoned that the global decline in CFC production, which fell and stayed below the 1974 peak level until 1983, bought time to develop scientific understanding without harming human health or the environment. They still believe that current emissions pose no immediate hazard to human health or the environment.

CFC industry shifts policy

Still, this fall producers and users of CFCs changed their position. In September, the alliance said it would support "a reasonable global limit on the future rate of growth of fully halogenated CFC production capacity." Fully halogenated CFCs, such as the most widely used CFC-11 and -12, are potentially the most robust depleters of stratospheric ozone. That same month, the nation's leading CFC producer, Du Pont, released its own statement that spokesman James Adshead concedes "may have gone a little bit beyond the alliance position."

Du Pont called for a limit on worldwide emissions of CFCs. "What that limit should be," Adshead says, "should be negotiated under the auspices of the United Nations Environment Program (UNEP)."

With 40 to 50% of the U.S. market and 20 to 25% of the world market—about $30 billion in total annual sales—Du Pont has muscle. According to EPA sources, the company flexed its muscle in 1978 and dissuaded the agency from taking more stringent measures than the aerosol ban it then put in place. This year's policy shift has been praised by some within EPA as an important first step, one that primes the pump for regulatory action. And the environmental group NRDC has proclaimed Du Pont's policy change "the biggest breakthrough" since EPA's 1978 aerosol ban. Why the industry shift?

Though the unexpected and still unexplained Antarctic ozone hole probably brought industry scientists and managers up short—as it did every researcher studying stratospheric ozone—a government scientist does not believe it to be a major factor in industry's reassessment. Several industry spokesmen confirm this. However, one, Allied-Signal's S. Robert Orfeo, chairman of the Fluorocarbon Program Panel of the Chemical Manufacturers Association, thinks "EPA might use the Antarctic hole as additional leverage to regulate." Not true, says John S. Hoffman, chairman of EPA's stratospheric protection task force. "We are not planning to base our decision making on Antarctica."

What did force industry to reevaluate its position, NASA's Watson believes, was the evolving science. Most scientists now agree that "large unbridled growth in the CFC industry would put enough chlorine into the atmosphere to deplete stratospheric ozone [significantly]," he says. Indeed, alliance spokesman Kevin Fay says, "large, unrestrained growth in CFC usage may lead to large future ozone depletion."

For many years, CFC production, and therefore demand, was essentially level. That changed in 1983 when CFC nonaerosol use began to climb. It continues to increase.

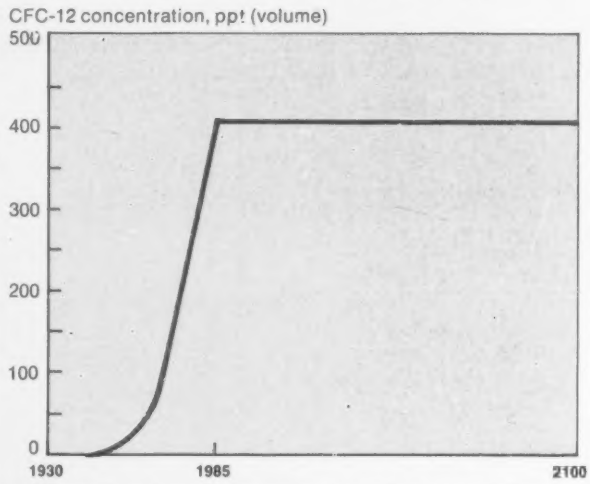
According to EPA, through the year 2000, the global short-term demand picture for the three most widely produced and used CFCs is for flat demand for aerosol applications of CFC-11 and -12; growth in the demand for CFC-11 and -12 in nonaerosol uses, particularly in the foam sector, at a rate paralleling economic growth of about 3% per year; and growth in the demand for CFC-113 ($C_2Cl_3F_3$) in solvent/cleaning applications, at a rate greater than economic growth, or about 5% per year. The long-term, or post-2000, projections are for continued worldwide growth. However, growth will level off in the developed countries and expand in the developing countries. The long-term demand growth for CFC-11 and -12, assuming mid-range future economic and population growth and technological change, is about 2.5% per year.

Watson also believes that another factor prodding industry's re-evaluation is the 1985 international ozone convention. That convention, signed by more than 20 nations and ratified by the U.S. and the U.S.S.R., calls for negotiating a protocol to protect stratospheric ozone. UNEP negotiations on such a protocol are to begin in Geneva next month. The outcome might be some sort of CFC production cap, or emissions limit.

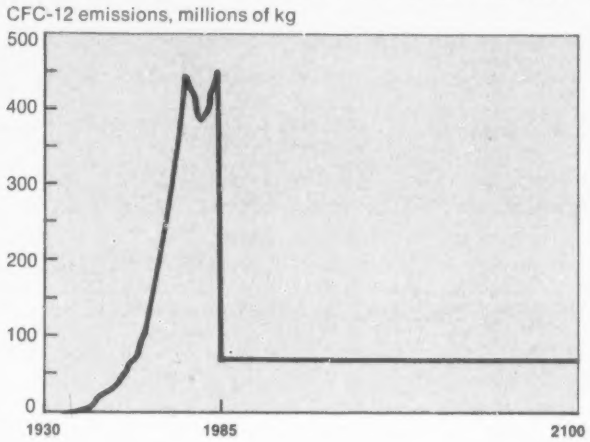
Indeed, in a statement to customers explaining why it deems it prudent to limit worldwide CFC production, Du Pont confirms Watson's assessments. In the statement Du Pont cites these facts:

- The recent upward turn in global CFC production and use, which now has reached levels that prevailed before the 1978 aerosol ban.
- The fact that all models now predict that a high sustained growth in CFCs, leading to emission levels 3 to 5% above current levels, would result in significant future ozone depletion.
- The contribution CFCs make to the climate warming produced by carbon dioxide and other trace gases, which some in industry say is about 15 to 20%, although several scenarios EPA uses place the contribution at about 30%.
- "The existing inability of the science to specify a safe long-term growth rate."

To hold levels of CFC-12 constant . . .



. . . emissions would have to be cut deeply



Emissions of chlorofluorocarbon-12, which has a lifetime of about 110 years, would have to be cut about 85% to hold its atmospheric concentration constant at today's level of about 400 ppt (volume). Levels of other long-lived CFCs, such as CFC-11 with a lifetime of about 75 years, behave similarly

With shades of the 1978 unilateral, use-specific aerosol ban darkening present U.S. regulatory horizons, industry has been quick to stress the undesirability of a repeat episode. Indeed, alliance chairman Richard Barnett, who is vice president and general manager of York International Corp., a CFC user company, says, "If the U.S. takes unilateral action, it takes the pressure off the rest of the world to act" to agree to an international accord. The association also insists that "regulation of specific uses of CFCs is ineffective and discriminatory."

According to the association's Fay, his group wants EPA to delay further regulations until there is an international protocol. Du Pont has gone one step further. It has asked EPA to consider using a regulatory negotiation process to reach a consensus position on any unilateral action EPA may take next year, and on the strategy the State Department will adopt this winter during protocol negotiations. As envisioned by Du Pont, the consensus position would be hammered out among EPA, the CFC industry, and environmental and public-interest groups.

"We would like to see an international protocol next year. We'd like to see that process go in parallel with the domestic process," says Richard Benedick, deputy assistant secretary of State for environment, health, and natural resources. Benedick, who will head the U.S. delegation to the Geneva meeting of some 40 nations, adds, "We don't want again to have a situation where the U.S. regulates domestically while the rest of the world sits back. I don't think that will happen."

The nation's second and third largest CFC producers, Allied-Signal and Pennwalt, also support the alliance policy. (Racon and Kaiser Chemical, the remaining two U.S. producers, had no comment.) According to Charles Coe, director of public affairs for Allied-Signal's engineered materials sector, his company especially agrees with the alliance's stress on "the international nature of this issue. It has to be addressed on a global basis."

"Until an international agreement is in place," Fay says, U.S. producers and users "plan to develop programs to decrease emissions." Both the alliance and Du Pont have already called for voluntary action by CFC producers and CFC end-user industries to reduce emissions through improved conservation and recovery practices.

Search for safe alternatives

Alliance chairman Bartlett says another way to manage the potential problem is for producers to develop new chemical formulations, and to shift production to these new, ozone-benign substitutes. According to Du Pont's environmental manager for the Freon products division, Joseph M. Steed, "The development of alternatives is going to happen at a rate that corresponds to the amount of pressure that is applied. Right now there is no economic or regulatory incentive to look for other routes."

Unilateral or global pressures could come from a production or emissions cap, a consumption or use cap, a tax on production, or marketable permits. "Any of these approaches has some kind of implementation difficulty," Steed cautions. But they all have one virtue. "They would raise the price of current products and/or tighten the market so that demand would increase for substitutes. In a sense, the market forces the development of substitutes or forces choices among uses. You might see certain parts of the market being very price sensitive—most likely the less essential uses—and these would drop away," Steed says.

Alan S. Miller, visiting assistant professor at the Washington (D.C.) College of Law, American University, says, "The ideal policy would be an international production limit set at current production, plus an

Chlorofluorocarbons find many and varied applications

Application, type of CFC used	Key characteristics of CFC used	Interaction with society	Economic scope (annual) Value of products/services ($ billions)	Direct CFC-related industry employment (thousands)
Refrigeration CFC-11 CFC-12 CFC-22 CFC-500 CFC-502	Thermodynamic properties Safety Cost	85 million household refrigerators 160,000 food stores 28 million household freezers 39,000 supermarkets 178,000 refrigerated trucks 250,000 restaurants 27,000 rail cars	$ 6	52
Air conditioning CFC-11 CFC-12 CFC-22 CFC-113 CFC-114	Thermodynamic properties Safety Cost	40 million homes; essentially all office, commercial, and public buildings	10.9	125
Mobile air conditioning CFC-12	Thermodynamic properties Safety Cost	60 million to 70 million automobiles and trucks (total in use)	2	25
Plastic foam CFC-11 CFC-12 CFC-114	Thermodynamic properties Safety Cost	Insulating foams for homes, refrigerators; food service trays and packaging; cushioning foams	2	40
Solvents CFC-11 CFC-113	Ability to displace all contaminants Chemically inert Safety	Microelectronic circuitry, high-performance air and spacecraft, and computers	Products valued at billions[b]	
Food freezants CFC-12	Thermodynamic properties Toxicologically safe Cost	Frozen shrimp, fish, fruit, vegetables	0.4	Less than 1000
Sterilants CFC-12	Nonflammability (safety)	Medical items, catheters, syringes, respiratory units, medical supplies, pharmaceuticals	0.1 (sterilizing equipment)	Less than 1000
			TOTAL $26.9[c]	**715[c]**

a Today CFC-22 and a blend of CFC-22 and CFC-142B can substitute for CFC-11 and CFC-12 in air conditioning and refrigeration with equipment modification. b Industry complexity precludes more detailed analysis for this report. c Does not include solvents, but does include all existing CFC refrigerators and air conditioners whose value equals $5.5 billion and employment amounts to 472,000. **Source:** Alliance for Responsible CFC Policy

emissions tax." Such a tax would be a substitute-forcing mechanism. It "would discourage long-term growth in emissions [but] it would be difficult to administer," Miller notes. Almost as effective, he says, would be a tax on production, with credits for documented recovery or destruction of CFCs.

Because CFCs accumulate in the atmosphere, the higher their short-term growth rates are, the greater will be the potential societal costs accompanying future regulation, Miller says. He also warns that producers could be hit with devastating costs if they are forced to reduce emissions rapidly.

"Industry has not greeted my proposal with overwhelming enthusiasm," Miller admits. "But [producers] can see one possible benefit from a tax—it would provide some certainty about future price," he says.

Industry, to put it mildly, was also not very enthusiastic about the 1978 aerosol ban. The ban did, however, prove to be an incentive—but a flawed one. "It did not provide any incentives for innovation in other areas, but it did get a lot of reduction," EPA's Hoffman says. Steed characterizes this use-specific ban as "disruptive" because it was imposed "too abruptly." Pennwalt's Julius E. Dohany, who is director of research and development for the fluorochemicals division, also cautions that further EPA actions or international controls should be phased in. "A transitional period will be needed," he insists.

Europeans to this day are against specific use bans. Says European Fluorocarbon Technical Committee's (EFCTC) John F. D. Mills, "Banning specific uses is very expensive; the social costs are high." He adds: "The longer you allow for adaptation, however, the easier the job, and the better the costs can be absorbed."

His argument was supported by the Japanese delegates to the UNEP/EPA Leesburg, Va., meeting in September on the socioeconomic implications of CFC control. Repre-

Direct potential alternatives[a]	Consequences of using alternatives
Ammonia Sulfur dioxide Methyl chloride	More toxic, combustible, corrosive, explosive, less energy efficient
Ammonia Sulfur dioxide Methyl chloride	More toxic, combustible, corrosive, explosive, less energy efficient
Ammonia Sulfur dioxide Methyl chloride	More toxic, combustible, corrosive, explosive, less energy efficient
None for high-efficiency insulation Pentane (some foams) Methylene chloride (some foams)	Less effective insulation, combustible, processing difficulties, toxicity
Perchloroethylene Trichloroethylene Trichloroethane	More toxic, use more energy
Cryogenic systems	Higher costs, use more energy, inferior quality food products, more costly to ship, use less consistent sterilization
Carbon dioxide	

sentatives of the Japan Flon Gas Association, and the Japan Aerosol Association reported that Japan's rapid cutback in CFCs used in aerosol products created a loss of aerosol markets, with an attendant increase in initial costs of converting equipment capable of handling other propellants. Consequently, the Japanese also called for a transition period.

Some in the U.S. environmental community agree that a transition period is needed to phase out the current CFC "bad actors," and to phase in more benign chemicals. Also at the September UNEP-EPA meeting, NRDC called for U.S. regulations and for an international agreement on a five-year phaseout of most of the production of the commercially available chlorine-containing CFCs and the bromine-containing Halons. Halons are used to extinguish fires in which the use of water would be harmful.

NRDC's plan calls for a 30% cut in these chemicals in 18 months. NRDC senior attorney David D. Doniger says this can easily be achieved globally by banning the aerosol use of CFCs in nations not yet restricting this use, and by prohibiting the use of blown foams for food containers in the U.S. (According to Allied-Signal's Orfeo, "blown foams from which egg crates and fast-food containers are made are very vulnerable to control.") The next step would be an 80% cut in production by the end of five years, and a complete phaseout in 10 years.

However, Doniger warns that even this time frame may be too long, and CFC cuts will have to be made now if the Antarctic hole can be linked to chlorine, or if the NASA satellite data showing ozone depletion at all latitudes can be confirmed. "Then we will be facing an emergency that will make Chernobyl [reactor accident] look like a trash fire at the county dump," he says.

Barring such an emergency, Doniger admits that selling the EEC countries on NRDC's phaseout plan will be very difficult. But, even if the EEC countries resist the plan, it should be imposed unilaterally on U.S. industry by EPA, he insists. However, he says EPA regulations also should "prohibit the import of CFC-derived products from those countries that have not agreed to the phaseout." For example, CFC-cleaned computer chips from Japan could be barred if Japan is not a party to a phaseout program. He thinks such a trade barrier might even be welcomed by U.S. producers.

Available and possible substitutes

CFC-22 ($CHClF_2$), which is environmentally safer than CFC-12, can be substituted for CFC-12 in mobile air conditioning with proper engineering changes. Thus, it can act as "a bridging compound" during the transition to chemicals such as CFC-123 ($C_2HCl_2F_3$) and -134a ($C_2H_2F_4$), which are even safer because they decompose in the troposphere, Doniger explains. Syntheses of these latter hydrogen-containing CFCs are known, but the compounds themselves are not available in commercial quantities. And they have yet to pass toxicity tests. Assuming they do so and become available in large volume, they can substitute for CFC-11 and -12 in refrigeration and air conditioning, Doniger says.

Doniger says U.S. CFC-user industries are pressuring U.S. producers to find safe substitutes for the major long-lived chlorine- and bromine-containing compounds now used. [These are basically CFC-11, -12, -22, -113, and Halon-1211 ($CBrClF_2$) and -1301 ($CBrF_3$).] Users are uncomfortable with the uncertain regulatory climate that could force existing CFCs from the market. They want to be assured of a stable supply—even at a higher price.

U.S. producers are facing other pressures as well. According to Doniger, "Rumors are floating that foreign producers may have a lead on U.S. producers in the area of substitutes." He has been told that the U.S. electronics industry believes the Japanese are hard at work on a substitute for CFC-113—the fastest growing compound in the CFC family. Its growth is pegged to the growth of the electronics industry where it is used widely as a cleaning solvent.

Whatever prods U.S. producers—be it phasedown regulations or foreign competition—"The CFC situation can be resolved by moving from one chemical to another [safer substitutions], and by wiser use of chemicals," Doniger says. By that he means better recycling and conservation. The phaseout program, he explains, "allows for a smooth transition for the industry and for consumers."

Interestingly, Hoffman says, "Environmentalists, on this issue, are calling for something innovative. They are not pushing us to do source controls." Yet he admits that EPA is "always going to be looking at the possibilities of doing source regulations"—that is, a specific use ban. But, he insists, the agency is "looking for something that is more innovative and will work better than"

the aerosol ban did. "The thing we want to do is make sure that [industry] has the opportunity to use its talent, ideas, and knowledge to come up with better methods. We have to make sure that we provide them with the right regulatory environment because of the financial incentives it provides, the certainty it provides," he explains.

New products in five years

The current lack of regulatory or economic incentives has not dampened internal deliberations at Du Pont. Howard Simmons, vice president of Du Pont's central research and development department, says his company is "considering a limit on production capacity [if that's mandated by EPA], and is researching alternatives." There have been some discussions on setting a timetable for the introduction of replacement chemicals, Simmons says.

Du Pont spokesman Adshead confirms this. "We believe that if there were regulations that limited the growth of the existing CFCs, and if there developed from that a strong market demand, then in probably five years or a little more, some of [the substitutes] we are working on could be made commercially available." Allied-Signal's Orfeo says that Du Pont probably "has the products/substitutes on the shelf ready to go but for the toxicity testing, which would take five to 10 years."

According to Du Pont's Steed, the company began looking for substitutes in the mid-1970s under a research program that has cost about $15 million. The research focused on fluorocarbons "that would avoid chlorine and would include hydrogen in the molecule," he explains. Lack of chlorine would eliminate the compound's stratospheric ozone-destroying potential, and the presence of hydrogen would prompt the molecule to break down in the troposphere.

Several compounds were eliminated in toxicity tests. Some could not be synthesized, or could not be produced without significant by-products. That left about a half-dozen chemicals, including CFC-22, -142b ($C_2H_3ClF_2$), and -152a ($C_2H_4F_2$).

CFC-22 is more costly to produce than the more widely used CFC-11 and -12. It also would require expensive retrofitting by automobile and refrigerator manufacturers because it operates at higher temperatures and pressures. Existing equipment using CFC-11 and -12 would have to be redesigned to accommodate CFC-22's different physical properties.

C&EN staff photos

Watson: science prodded re-evaluation

CFC-142b and -152a are now produced in small quantities, as raw material for polymer production. They are expensive to make. And in addition, they are flammable, Steed says, and are not suitable substitutes in refrigeration, air conditioning, or solvent/cleaning applications.

The remaining unnamed chemicals show promise, Steed says. They are undergoing toxicity tests and process development. "If we were able to produce them, we know they would be several times as expensive to produce as current products, and that's assuming we can overcome the remaining problems," Steed adds. "At best [after all the expensive development and testing] we'll come up with something that is similar to what's already on the market at a much lower price."

Orfeo: $10 million for alternatives

According to Orfeo, Allied-Signal has spent more than $10 million searching for alternatives. And still, spokesman Coe says, Allied-Signal "has not been able to find substitute products that have the same unique characteristics the CFCs as a group have." The company continues to look for alternatives. Coe says any decision on substitutes will have to factor in cost and retrofitting problems in the user sectors.

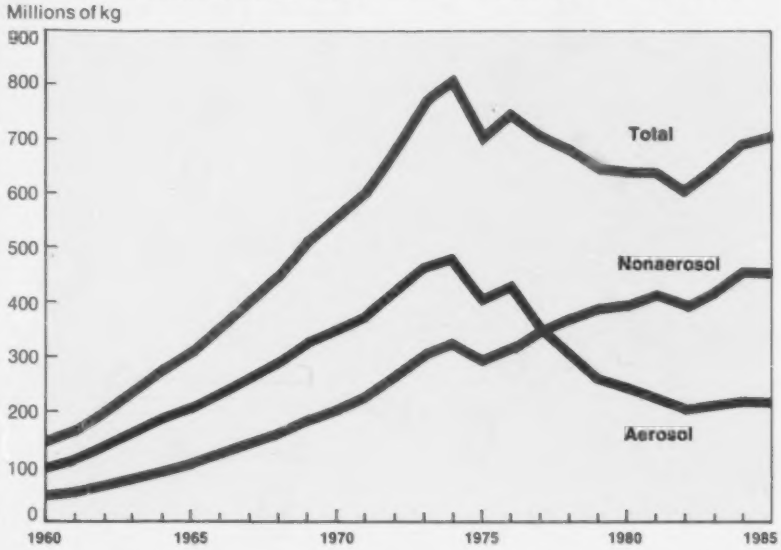
Dohany of Pennwalt says a blend of CFC-142b and -22 can substitute for CFC-11 and -12 in air conditioning. The blend's use, however, requires engineering modifications in end-use equipment. The same blend can substitute for CFCs used as aerosol propellants. Both compounds have passed critical toxicity tests. As mentioned, another promising chemical, CFC-134a, has yet to pass toxicity tests.

Search for control strategies

So while industry searches for substitutes, EPA searches for an equitable, and innovation-stimulating control strategy that will appeal to domestic producers. It also wants this strategy to entice other nations to agree to a global ozone protection program. In addition to NRDC's phaseout plan, three other options are being considered seriously. These are a production-capacity cap, a production cap, and the so-called Canadian proposal, which sets a global emissions ceiling that is implemented through national consumption (use) limits.

A production-capacity cap prevents additional plants from coming on-line and, according to EPA, implies a production limit. EEC has agreed to such a cap. The drawback is that European industry is probably at only about 70% of its full capacity, which means it could pro-

CFC production rising again after dropping in mid-1970s



Total reported production of chlorofluorocarbon-11 and -12 peaked in 1974 at 813 metric tons and declined fairly steady until 1983, when it began rising. Aerosol applications declined in the mid-1970s and are only now beginning to grow slightly, but nonaerosol uses have continued to increase. The production total for 1985 of 703 metric tons is the combined output of 21 companies in North and South America, Western Europe, Japan, Australia, Africa, and India. No information on CFC production from China, the Soviet Union, and Eastern bloc countries has been available since 1983. However, the U.S.S.R. recently reported its annual production capacity of CFC-11 and -12 is 60,000 metric tons, and China revealed its production capacity for those CFCs and several others is 18,000 metric tons. **Note:** The aerosol/nonaerosol divisions prior to 1976 are estimates. **Source:** Chemical Manufacturers Association

duce at least 40% more CFCs per year. It also means that emissions could continue to increase into the next century before the cap became effective. In contrast, a production cap sets an absolute production limit. That limit could be set at the current production level; the 1974 production level, which was the highest ever; or 1.5 times the current level (which is about the EEC production capacity cap).

Europeans concede that controlling CFC uses (like an aerosol ban) would encompass production, imports, and exports. But as Mills points out, by controlling production, "you are controlling everything—not just CFCs in bulk, but CFCs in aerosol cans, in foams, and in refrigeration units." Because there are fewer CFC producers than users, Mills says control of production makes sense administratively.

European environmentalists are not necessarily pleased with Mills' arguments. They say the EEC production-capacity cap doesn't curtail current use or emissions. In fact, total EEC CFC capacity has gone from 480,000 to 537,000 metric tons. Aerosol use has leveled off, but CFC use in foams for insulation and for industrial solvent cleaning has climbed significantly. However, EEC is putting much faith in its newly minted codes of practice, which it hopes will cut CFC emissions. Environmentalists concede that, in theory, the production-capacity cap would restrict growth in the future. But, they argue that a problem with setting production-capacity caps is that the price for CFCs could rise to a point where producers are making quasi-monopoly profits.

Christopher F. P. Bevington, an economist with the London-based Metra Consulting Group, who has done the economic and social cost/benefit analysis of CFC control for EEC, tends to discount this concern. Though the price may be higher, he says, there is "more incentive to develop substitutes. Moreover, by complying with the production cap, manufacturers are forgoing the alternative of selling a lot more at lower prices. The profit margin might seem to be excessive, but probably not profits per se."

"From a purely scientific perspective, the logical [option] is a cap on the amount of chlorine being put into the atmosphere—a cap on emissions," NASA's Watson says. Although he says he has no special insight into EPA or UNEP deliberations, Watson believes "a number somewhere around one to one and a half times current production rates will be given the most serious consideration. There won't be major cutbacks, nor significant growth." (Production equals emissions to a first crude approximation.) Watson would be surprised "if there was a draconian cutback on the use of CFCs."

Pennwalt's Dohany also sees no outright ban, especially for CFC-11 and -12, "which are going to be needed for a long time to come." He believes the "likely outcome" of EPA deliberations will be threefold: stringent control on CFC releases, a phasing in of substitutes for CFC-11 and -12, and a ban of these two compounds by a certain date. This can all take place under some kind of internationally imposed production or consumption ceiling.

Canadian consumption proposal

The Canadian proposal is basically a global consumption limit. Consumption is defined as production plus imports minus exports minus recovery and conservation (if and when such programs are ever put in place). As proposed, 25% of the consumption limit would be allocated among nations based on their share of world population, and 75% of the limit would be apportioned among nations based on their share of the world gross product. Such a weighting would give developing countries a share of the global ceiling. This would allow them to produce CFCs if they choose to do so in the future, mainly for refrigeration purposes. The global limit could

be set, Environment Canada suggests, at the maximum production level ever for CFC-11 and -12, which was 812,000 tons in 1974.

According to Hoffman, attendees at the September meeting expressed a lot of interest in the Canadian proposal. The proposal bridges the gap between the earlier U.S. and other countries' call for a worldwide ban on nonessential aerosol uses of CFCs, and the European call for a production-capacity cap. EPA is seriously studying the consequences of this proposal.

European delegates to the Leesburg meeting in September found the Canadian proposal "a constructive idea, worth thinking about," Bevington says. "But it was sprung at the last minute," leaving the Europeans with many unanswered questions. How would it be implemented? How enforced? Would CFCs per se be considered, or would CFCs imported in refrigerators be included, for example?

The key attraction of the Canadian plan is that each nation could decide which uses most need CFCs. France, for example, might decide that using CFCs as aerosol propellants in fragrances and mousses is important because CFCs make better products than alternative propellants do. On the other hand, Scandinavian countries might be more inclined to use CFCs in foam insulation as part of energy conservation efforts. And, of course, countries such as the U.S. might find CFC use in automobile air conditioning a socially significant application.

As equitable as the Canadian proposal appears, Bevington predicts that for the time being EEC delegates to the negotiations in Geneva will work with the present European system of a production-capacity cap. A spokesman for one European CFC producer concedes, "The production capacity in Europe is much less utilized than in the U.S. and Japan." He adds, "There may have to be a deal. EEC might have to reduce its production limits to try to even out the world situation."

From a bargaining standpoint, Miller says the U.S. should probably come to the negotiating sessions

Hoffman: something more innovative

with a proposal closer to the Canadian consumption scheme than to the European production-capacity cap. If it doesn't, he says, "the U.S. will end up with the European approach." The Canadian proposal, however, "addresses the second-order question of how to [set a limit], not the first-order question of what that ultimate limit" should be, Miller says.

If Bevington's prediction is accurate, getting the 12-nation EEC on board the Canadian proposal will not be easy. Britain, especially, is thought by knowledgeable U.S. sources to be very skeptical of the need for controlling CFCs. This perception may be incorrect, however.

According to Lucas Reijnders,

Bevington: a production-capacity cap

head of the environment section of the Dutch Foundation for Nature & the Environment in Utrecht, "It is usually the U.K., France, and Italy against any serious [environmental control] measures. Now the U.K. is starting to change its position, with France and Italy still against [CFC] controls." In EEC negotiations on CFC controls, Italy is usually represented by a CFC producer, and France tries to protect its cosmetics industry, explains Reijnders.

He also points out that the most serious resistance to CFC controls comes not from the producers, but from users—from the manufacturers of cosmetics and foams, and from the refrigeration industry. "These are more important politically," he says.

The State Department's Benedick concurs. "The big question mark is how European industries react. Industries have more political power and control in Europe because there are no counterbalancing forces there." The environmental groups and the press have not been so interested in the ozone issue as they have been in control of acid rain. Moreover, "Many European delegations send only industry people to [UNEP] meetings," Benedick explains.

The U.S. has decided on its negotiating strategy for next month's UNEP meeting in Geneva. It will seek a near-term global production cap on CFC-11, -12, and -113, and Halon-1211 and -1301 "at or near current levels," and a gradual phaseout of these ozone-depleting chemicals over the longer term. The intent is to lower emission rates, but how great a cutback is needed "has not yet been decided," Benedick says.

EPA's schedule of arriving at a domestic regulatory position on CFCs is unchanged by the U.S. international posture. (On May 1, 1987, EPA will issue its regulatory proposals; and in November, the final regulations, if any, will be promulgated.) "The State Department's Geneva proposal doesn't affect us," says Stephen R. Seidel, a senior analyst in EPA's office of strategic studies. "It would be our position only if the rest of the countries agreed to it," he adds.

However, more than three dozen other nations are involved in these UNEP negotiations on a global ozone protection protocol. And many are likely to offer other proposals.

Outcome of negotiation doubtful

There is still much uncertainty about what the outcome of the ozone protection protocol process will be. "I remain doubtful that the process will produce a result adequate to meet short-term [U.S.] political considerations," Miller says.

Edward J. Woodhouse, who teaches political science at Rensselaer Polytechnic Institute and who recently coauthored "Averting Catastrophe: Strategies for Regulating Risky Technologies," agrees. He is pessimistic about "a concerted strategy—like a monetary conference—being developed for protection of stratospheric ozone." The Organization for Economic Cooperation & Development countries, which produce and use 80% of the world's CFCs, will take action only if the science is compelling, he says.

Some of the science being sorted out points strongly to the bridging role CFCs play in both ozone depletion and climate warming. At a pivotal scientific meeting held last year in Villach, Austria, scientists concluded that CFCs as a group may, within the next few decades, become the second most important greenhouse gas after carbon dioxide if no preventive steps are taken. (Global CFC atmospheric levels are growing at about 5 to 7% a year, and the compounds have long-lived residence times in the troposphere.) The scientists also concluded that CFC control was easier than limiting or reducing carbon dioxide emissions.

"If we can set up a protocol that is designed to provide an intelligent path for global airshed management—the apportionment of CFC emission limits equitably among the various countries—then we will be in a position to use that experience to draw a later agreement on greenhouse gases. CFC control provides a relatively simple opportunity to learn," Michael Oppenheimer, a senior scientist with the Environmental Defense Fund, believes. □

Response to global warming

The overwhelming consensus of scientists studying climate change is that the chemical forces that will alter climate during the next century are starting to do their damage now. Pressure thus is growing on the U.S. and foreign governments to begin taking immediate steps to avert catastrophe or at least establish policies of adaptation to the inevitable changes.

"These are no longer just science issues," declares Sen. John H. Chafee (R.-R.I.), "they are policy issues." Chafee heads a Senate environment subcommittee that held hearings on climate change and threats to the ozone layer last June.

Two months later, in August, the Senate ratified the convention for the protection of the stratospheric ozone layer. In further action, Congress appropriated an extra several million dollars to the Environmental Protection Agency for upgraded programs and research on the chemical threat to climate and the atmosphere. And another bill requiring the President to plan an International Year of the Greenhouse Effect passed. Other, more sweeping, measures were introduced.

Activists believe policy action can start to be taken now. The federal government, for example, can help coastal cities begin factoring into their 30- to 50-year public works plans the likelihood of a sea-level rise of up to 2 feet by 2050. It can rethink its own water resource programs for a time when rainfall patterns change drastically. Department of Energy analysts could devise alternatives to the burning of fossil fuels as energy sources. Research could be sponsored on new process technology aimed at further energy efficiency and reduced waste products. In the larger policy spectrum, the Administration could begin requiring that environmental impact statements for planned construction projects include climate scenarios.

This is policy making on a grand scale. And it isn't easy. First of all, the issue is international. Alleviating disaster can come about only if enough countries act. Second, any restrictions put on industrial activities will be expensive and politically hard to achieve. Third, it isn't one gas that affects global dynamics. It is predominantly four: chlorofluorocarbons (CFCs), carbon dioxide, nitrous oxide, and methane. Each gas has its "sociology"; each its economics; and therefore each its regulatory complexities.

Further, scientists don't yet know region by region what the changes will be. Regional impacts projected by the major computer models all differ. And finally, the Administration does not yet have a climate change policy. What it does have is a bedazzling collage of programs with specific, interrelated titles.

The policy debate

Pressures to establish policy—sets of goals with steps to achieve them—have their origin, naturally, in various environmental groups. A major actor is the Natural Resources Defense Council, which successfully won its suit against EPA to force the agency to move more quickly in regulating CFCs. The World Resources Institute has taken an overall policy lead by issuing studies on consequences and laying out policy options. The Worldwatch Institute has done continuing studies geared toward explaining the ecological consequences of industrialization. The Conservation Foundation is preparing ambitious policy documents of its own. The Environmental Defense Fund and Sierra Club both have active programs of education, information, and public policy.

Controlling carbon dioxide: the view from Europe

So far, there has been little official activity in Europe addressing the specific question of carbon dioxide emissions and global warming. But that situation is beginning to change.

The European Parliament—legislative advisory arm of the European Economic Community—recently issued a report on research and energy policy measures to deal with the "rising concentration of carbon dioxide in the atmosphere." The report essentially recommended that because some warming effects were in the offing by the end of the century, cuts in carbon dioxide emissions of at least 2% a year should go into effect immediately.

This led the parliament to adopt a resolution calling for reduction of carbon dioxide emissions. It said major means of reduction should be energy conservation measures. It called, too, for stepped-up programs of reforestation in Third World countries, as well as programs to give those countries access to advanced energy know-how.

The resolution is one small step forward in a coordinated European policy toward carbon dioxide regulation. It will go to the Council of Ministers of EEC, which will decide whether to put it into effect. Once in effect, the EEC nations would be bound to enforce it.

"Interest in the greenhouse effect is picking up now," says Lucas Reijnders, head of the Environmental Protection & Resources Group of the Dutch Foundation for Nature & the Environment, in Utrecht. "The current coalition government [in the Netherlands] wants to put more energy into the carbon dioxide problem."

Such interest is triggered by the tendency of the Dutch to equate the greenhouse effect with rising sea levels, a matter of major concern to this low-lying country. But complicating the issue, Reijnders says, is overwhelming popular opposition to nuclear energy, a major substitute for fossil fuel power.

"Other countries," says Reijnders, "don't feel [the greenhouse effect] is much of a political issue. And we want to change this." To that end, Reijnders is spearheading a major conference on the greenhouse effect in Europe at the end of next year.

Whether his and related environmental groups really can change the views of the other European countries is problematical. Coal is an important fuel in Europe—more so after the disaster at Chernobyl. So the trend is really away from any controls on fossil fuels. The Labour and Conservative parties in the U.K., for example, have been debating energy options, but in economic terms, rather than from considerations of the greenhouse effect.

Three years ago, Britain's Central Electricity Generating Board commissioned a study into "man-made carbon dioxide and climatic change." But the upshot was mainly a list of energy conservation measures that could be employed to reduce future effects.

In Eastern Europe, whose energy policies Reijnders has been tracking, "there simply are much more pressing problems than carbon dioxide," he says. "In Poland and Czechoslovakia, for example, coal dust is the main concern as an environmental threat. And we all get a feeling that the U.S.S.R. would not mind a warming up anyway. Awareness will come, but not for a time."

European researchers and environmentalists are aware that agriculture-based methane and nitrogen oxides also contribute to climate warming or ozone depletion. But work on controlling them is nonexistent. "These gases merit more study, especially in the percentage of their impact on the atmosphere, but it is doubtful that we could bring their levels down 30 to 40%," Reijnders says.

So while scientists urge more study, the environmental community is pushing for action. Gus Speth, president of the World Resources Institute, states the basic philosophy. "When dealing with risks that are grave but cumulative and irreversible, uncertainty is a strong argument in favor of action. We must take whatever steps are feasible as soon as possible to reduce the dangers."

EPA Administrator Lee M. Thomas agrees in part. "We're talking about pretty substantial global changes," he says. "So here at EPA we're trying to develop a general scientific consensus on the causes and effects and then a general consensus on solutions. This is something that's going to take some time. We're working to participate better in interagency discussions and be more formal in the way we're assessing both the scientific and policy issues associated with climate change."

Thomas believes prevention is the policy course of choice. "I can understand why people say adaptation is the most practical tack to take, but I'm not prepared to make such a statement," he says. "Over the next several years we could begin to know that the environmental effects could be too severe. I think we're going to work both sides simultaneously. We're going to look at our options as far as control is concerned, on the variety of gases we know of. At the same time we're going to work more aggressively on the effects side. In the meantime I have a prevention bias."

But Alan Hecht, head of the National Climate Program at the National Oceanic & Atmospheric Administration, appears to lean toward a policy of adaptation. "It's hard to conceive that this thing can be controlled globally," he says. "I think we'll adapt one way or another. What it really all comes down to is economics—shifting the burdens and the impact so that the fewest people are hurt."

Pace in Congress picks up

Congress is beginning to quicken its pace in dealing with the legislative aspects of both the ozone and greenhouse issues. There will be some preparatory action when the new Congress assembles in January. Then all the relevant bills introduced in the last Congress will be reintroduced. And, at the same time, the National Academy of Sciences will brief Congress on climate change to give legislators a strong grounding in the scientific issues. Soon after, various commit-

tees will begin oversight hearings.

Congress began to stir on global climate as it was winding up its work last month. In last-minute action, an amendment was added to the National Science Foundation's appropriations requiring the President to plan for a 1991 International Year of the Greenhouse Effect. It directed the President to give Congress a progress report on those plans no later than next Aug. 1. The White House Office of Science & Technology Policy will be working on the President's response. In other action, EPA received $5.6 million to conduct research on ozone depletion and climate change, an increase of $1.75 million over fiscal 1986.

In the House, Rep. Bill Richardson (D.-N.M.) introduced the Stratospheric Ozone & Climate Protection Act of 1986. The bill—H.R. 5737—essentially says that if the Geneva ozone protection protocol negotiations that begin Dec. 1 are not moving fast enough, the House will consider legislation mandating phaseout over five years of at least CFCs and bromine-containing compounds. U.S. production of the man-made compounds listed as climate-changing and ozone-depleting would be cut 50% within two and a half years of being listed, and phased out entirely over five years—unless EPA hastens reduction through rule making. The bill also would ban imports of listed compounds or products made from or with them, unless EPA certifies that the exporting country is in a phaseout program with a pace equivalent to that of the U.S.

In the Senate, Joseph R. Biden Jr. (D.-Del.), Claiborne Pell (D.-R.I.), and Charles McC. Mathias Jr. (R.-Md.) introduced the Global Climate Protection Act. That bill would create an executive branch task force on the global climate, chaired by the Secretary of State with the head of EPA serving as vice chairman and executive director of research. The task force would develop in a year a governmentwide strategy to assess "the threat raised by global warming and to respond to that threat by national and multinational means." Three months after the task force's report, the President would submit the strategy to Congress with specific recommendations for further legislation.

Under the bill, the President also would appoint an ambassador-at-large to coordinate and lead U.S. participation in the International Geosphere & Biosphere Program, a newly approved international attempt to understand through satellite monitoring, supercomputer technology, and Earth-based research the dynamics of atmospheric forces.

"One duty of this ambassador," says Biden, "would be to seek early designation within the United Nations system of an International Year of Global Climate Protection. The legislation also calls on the President to put global warming on the U.S.-Soviet policy agenda."

Whether any new legislation will be successful is problematical. What is significant is that only a handful of Senators and Congressmen seem concerned about the issues. The overwhelming numbers of legislators from the Gulf and lower Atlantic coastal states and from the farm belt—areas that could be hardest hit by droughts and a sea-level rise—have been silent. There is far less than a critical Congressional mass over the issue, and it would probably take imminent catastrophe to create it.

Sen. Albert Gore Jr. (D.-Tenn.), who spearheaded the idea of the International Year of the Greenhouse Effect, thinks that time is near, especially if extremes in local weather patterns continue to occur. "Because of three hot years in a row," he says, "the drought caused an economic catastrophe in the Southeast this year," he says. "These changes, which appear to be small when you look at the numbers, have tremendous economic effects and will have tremendous political effects."

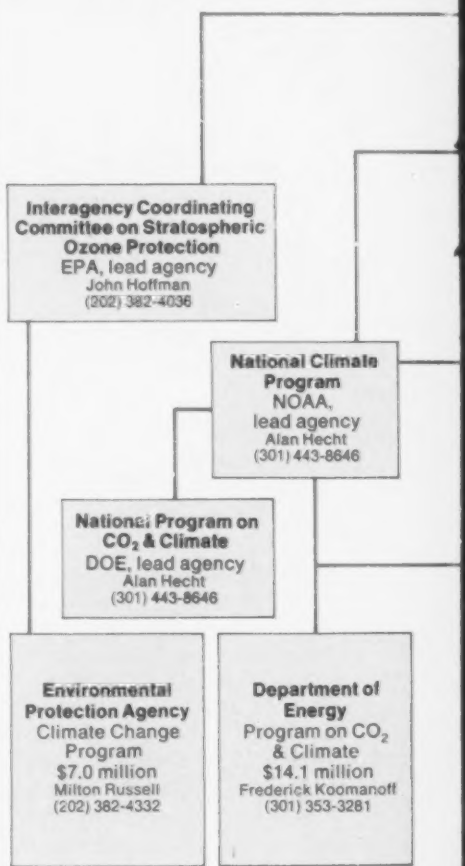
Collage of climate studies

It would be reassuring to report that the federal government is poised and organized to deal with the policy impacts of climate change. But though the government is beginning to try to put its climate change house in order, that unfortunately isn't the case.

One key observer of the whole climate change issue is David Burns, who heads a 10-year-old climate variability program at the American Association for the Advancement of Science. "I've been working on the climate change issue for several years now, and I still don't have a clear perception of where the authority lies. There's a lot of tugging and pulling going on."

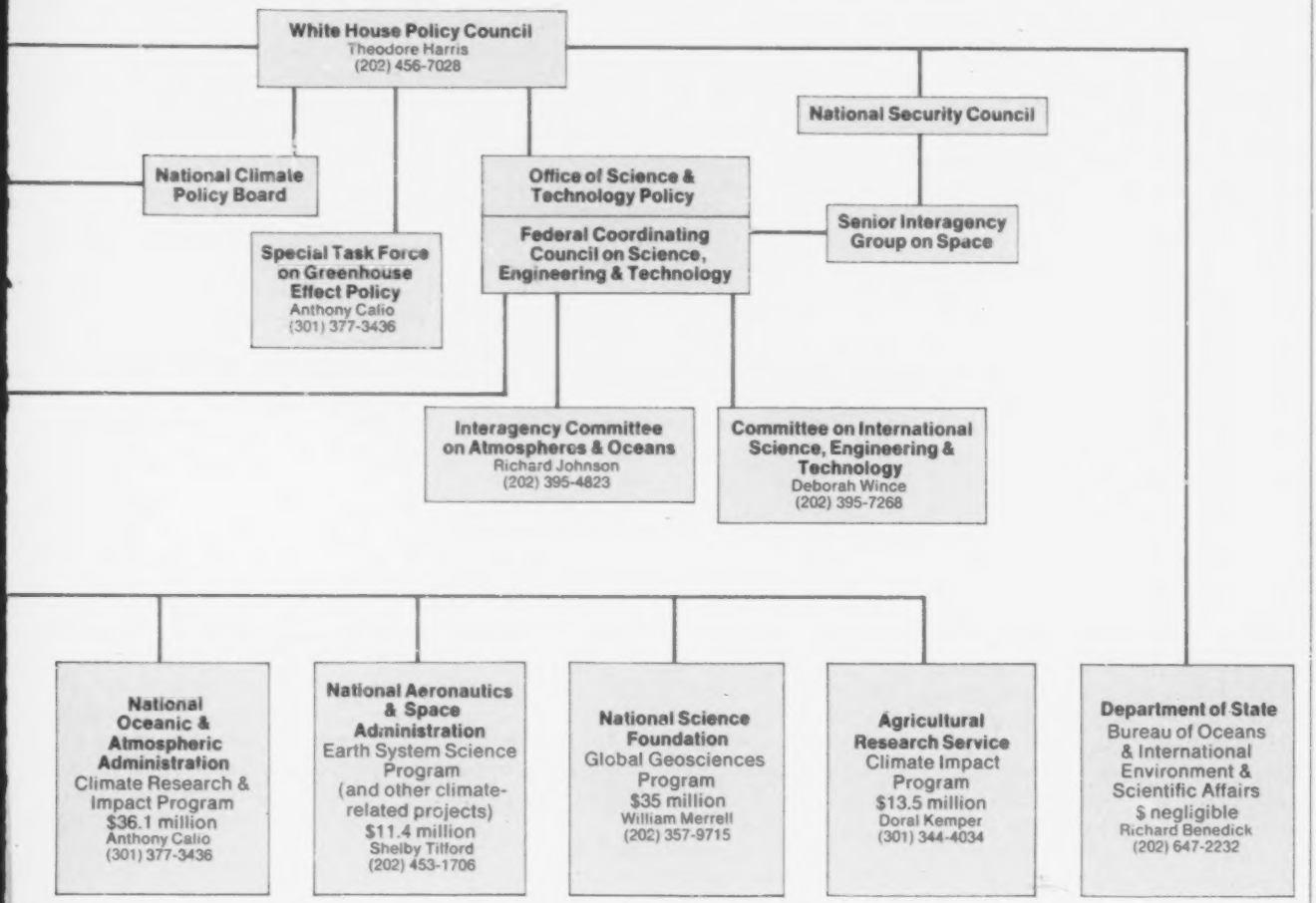
The problem is coordination. There do appear to be more than enough agencies with specific missions to do specific things. There exists a National Climate Program (NCP) run by NOAA in the Commerce Department. It is the result of legislation promoted by Rep. George E. Brown Jr. (D.-Calif.) for an interagency program to oversee climatological research across several agencies. NCP covers a whole range of climatological issues, from research needs in the forecasting of

U.S. climate change research



Note: Dollar figures are for fiscal year 1986

and policy programs are separate and uncoordinated



tornadoes, hurricanes, and floods, to gaps in the modeling of climate trends. NCP in turn has a policy counterpart in the form of the National Climate Policy Board, which meets to make recommendations on national policies underscored by climate and weather.

In addition, there is an interagency group on the ozone layer coordinated by EPA, from a policy planning and evaluation office headed by John Hoffman. This group's efforts feed into the climate change issue because of the role CFCs play in climate warming. For climate change induced by carbon dioxide, however, DOE is the lead agency. NASA designs and launches the satellites that monitor the chemistry at various altitudes, longitudes, and latitudes, besides conducting state-of-the-art modeling work on climate trends. NSF supports basic research on weather and climate dynamics.

But too many agencies speak only for themselves. "The issue of who speaks for whom is an important one because an orderly process needs to be developed," says NOAA's Hecht. "The CFC/ozone issue is in good shape," he says. "There is a lead agency—EPA. A timetable of meetings has been scheduled nationally and internationally to establish policies for the control of CFCs and other ozone-depleting chemicals. As a result there is a process under way to reach a U.S. position to present internationally. To some extent there will be controversies over to what degree industry regulates itself, and to what degree government must regulate. The greenhouse gas issue is more complicated."

Perhaps the biggest need is resolution of the continuing squabble between EPA and DOE over which agency should set the research agenda for studying climate change. There is a strife-packed history behind the current impasse.

Conflicts began in 1983 when EPA released two reports on climate change—one on warming trends, the other on sea-level effects. The first was released to the public a few days before the National Academy of Sciences issued its own report on global warming. The academy persuaded then Presidential science adviser George A. Keyworth II to issue a formal reprimand to the EPA researchers for making what the academy panel and DOE felt were unsubstantiated conclusions.

Up to that time, DOE was the leading government voice on cli-

mate warming through its program on carbon dioxide/climate research. EPA's two reports, besides shocking DOE by their sudden emergence, created enormous media attention. They warned not only of coming changes but that the warming issue was not so simple as DOE's carbon dioxide-focused research program implied. As the EPA documents reported, not only carbon dioxide but three other gases were contributing to the warming. DOE's program was suddenly inferred to be too narrow in scope. DOE thus saw the EPA reports as the opening salvos of a power grab.

A source in NOAA claims the solution could be simple. "The best advice I'd give EPA," he says, "is to concentrate on its charter and work very closely with NASA, DOE, etc., to explore the policy and impact issues. They shouldn't do climate research. They should build bridges so we can all work as a team. EPA has done a lot of things people in the other agencies were not made aware of. The worst thing that could happen is for EPA to isolate itself."

"I'd suggest," says an EPA source, "that it's the DOE program that's the isolated one. We are the ones sitting in the middle of the issue. It's unfair to be putting us on the extreme end. There aren't many reasons why the warming issue should be in DOE anyway. The issue was originally construed as as an energy policy problem, and there was fear that it would be handled inappropriately by another agency. I don't think that's the case any more. We are not going to tear down all the fossil fuel plants in the country. That's crazy. I was glad to see Sen. Chafee actually admit in the last session of Congress that there could come a time when we may need to consider the need for more nuclear power." He adds that if he were a member of DOE's upper management, he would try to use this new information on other gases to DOE's advantage, instead of fighting the trend.

NOAA, too, would like a stronger role in setting research policy. But it has had to be shy about showing any muscle. NOAA is a weak agency. During almost every budget cycle, the Office of Management &

Program aims at developing global atmosphere research

The problems of climate change are global, and if countries are to mount a truly systematic approach to understanding how industrial activities induce such changes, a strong international research program is needed. This is beginning through a new effort known as the International Geosphere & Biosphere Program, coordinated by the International Council of Scientific Unions, which approved the massive venture in September. The National Academy of Sciences is the U.S. secretariat for IGBP, and the federal government is in the process of establishing an interagency structure for coordinating U.S. involvement.

"IGBP," says an ICSU briefing document, "will be a carefully designed program of research directed at providing the information we need to assess the future of Earth in the next 100 years, with an emphasis on processes that change on time scales of decades to centuries. It will be a program of basic research with almost immediate practical applications in the management of resources at national and international levels and as a means of improving the reliability of warnings of global change of significance to our environment and to humankind."

Two technical developments have made such an undertaking possible: the satellite and the supercomputer. With satellites, scientists now can view a vast array of physical, chemical, and biological changes in global dynamics. And the computer can integrate them and develop patterns and thus predictability. But the data problems are massive. The National Aeronautics & Space Administration, which will feed data to IGBP, is up to five years behind in translating from its tapes the digital information on ocean winds and waves, cloud movement, and chemical transformations in the upper atmosphere obtained by satellite monitoring.

"Over the next decade the flow of data will increase from thousands of observations each day to many millions of observations," says an earth sciences policy report produced by the Office of Science & Technology Policy in 1985. "Digital data rates soon will increase from 100 billion bits per day to over 10 trillion bits per day. Some capability for sorting that data for important information and managing the data streams is essential. Proper handling of all these data at affordable costs is probably the biggest technological challenge to be faced in the program."

Putting data management problems aside, there still remains a slight flaw in the IGBP research framework. IGBP is primarily a physical science program. Atmospheric scientists and oceanographers have been working together for years on various interdisciplinary projects. Biologists, on the other hand, have not. Only a handful of ecologists have much experience working with each other and their physical science counterparts.

"It's true that the biological/ecological aspects of IGBP are not well organized. It's hard to get a handle on them," says NAS's John Perry. There are only a few ecologists who study large geographic areas. And they have no research center on the scale of the Boulder, Colo., National Center for Atmospheric Research (NCAR). "You'd think the biologists would be well out front on this [issue of climate change]. But that isn't the way biology works," Perry explains.

Social science and the almost forgotten science of geography, too, have been excluded in government climate change programs, especially in the Department of Energy's programs, Perry says. The social sciences will almost certainly have to be included because IGBP's objectives stress human impact, Perry points outs. As for geography, one source says, researchers in that field "are always off huddling by themselves."

William Merrell, assistant director for geosciences at the National Science Foundation, says he isn't too worried about any biology gap in either IGBP or NSF's global geosciences program. NSF's directorate in biological and behavioral sciences is slowly folding some of its programs into NSF's global geosciences program, and that in turn will fold into IGBP, he says.

Furthermore, NSF's assistant director for biological and behavioral sciences, Frank Harris, has made many trips to NCAR, which NSF funds, to begin the interaction between the physical and biological scientists. "These visits will change the way ecologists think about global systems," says Merrell.

Budget has tried to eliminate it by selling off to the private sector its satellite monitoring and weather forecasting functions. Each time NOAA has fought off such attempts. Focused mainly on its own survival, it was never in any position to play interagency turf politics.

NOAA is indeed a key agency if only for the simple fact that its main mission is to do research on weather and climate and provide forecasts and warnings. Its mission is clear. It has no soaring ambitions except to increase its research program. Its biggest problem is maintaining its mission in the face of attempts by some quarters at NASA to grab away important meteorological research. That conflict, although extremely nettlesome to NOAA, is, however, nowhere so severe as the trench warfare between EPA and DOE.

Coordination to be worked out

By the end of the year, the White House Domestic Policy Council, through its working group on environment and natural resources, is expected to produce a position paper on how the agencies should be organized to deal with climate change as a policy issue. The council has appointed NOAA's Administrator, Anthony Calio, to head a task force to determine Administration policy on the greenhouse issue.

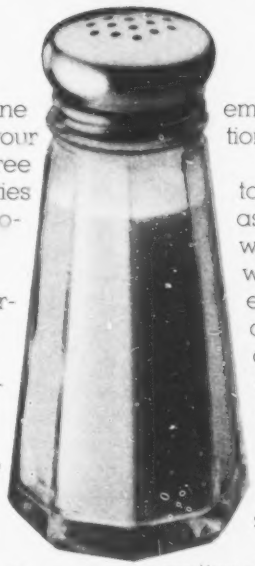
"We're trying to come to a common Administration position on greenhouse," says a council source. "A number of us believe there is a need for some sort of guidance that can be given to all the agencies concerned with global warming. We will try to arrive at a government position, make linkages between economics and policy, include agency coordination, and decide on levels of agency funding over what periods. We then will give a briefing to the department Secretaries."

The council also is trying to coordinate the U.S. role in the new International Geosphere & Biosphere Program with NASA's earth systems science program and with NSF's Global Geosciences Program. "There is obviously a tug of war going on among NASA, NOAA, and NSF as to who is the biggest kid on the block," says the source. "But there's a role for everybody.

"I don't think you'll see a clear czar with respect to global change," says the source. "We have several layers of bureaucratic systems that can handle the coordination problems. The agency with the strongest voice coming out of all this will be DOE. It will be a reluctant bride, but energy production still seems to be the critical issue in warming," says the council source. In any case, interagency coordination draws cynical commentary these days. "Right now coordination is about as nice a job as shoveling garbage," says one atmospheric sciences official. "The agencies come together only when they're desperate for money."

Meanwhile, EPA is taking its cli-

Our new hydrazine production process leaves out something you should do without.



ATOCHEM hydrazine hydrate helps put your product on a salt-free diet. In fact, impurities such as sodium chloride and heavy metals that can adversely affect performance in pharmaceutical and agricultural syntheses are practically nonexistent.

The hydrazine we produce is extremely pure because of the ingredients we use; or, rather, *don't* use. Our patented process substitutes hydrogen peroxide for the sodium hypochloride employed in conventional processes.

What we can *add* to your hydrazine is as important as what we leave out. We'll work with you, for example, to develop and supply various concentrations specifically formulated for your application. And our vast resources help ensure a steady, reliable supply.

For more information about the high-purity hydrazine you shouldn't do without, just fill out and return the coupon below. Or call (201) 652-8575.

Yes. I'm interested in using ATOCHEM hydrazine.
Please ☐ send me more information. ☐ have an ATOCHEM representative call me.

Name _____ Title _____
Company _____
Address _____
City _____ State _____ Zip _____
My application is _____

Return to:
Olivier Meurzec, Marketing Manager
ATOCHEM INC., Chemical Division
P.O. Box 607, Glen Rock, NJ 07452

ATOCHEM INC.
elf aquitaine group
ATO

inspec
The Institution of Electrical Engineers

ONE OF THE WORLD'S BEST-KNOWN ENGINEERING DATABASES!

AT ITS BEST ON STN INTERNATIONAL

- Mounted on STN as a single file
- Citations from 1969 to present
- You'll find:
  - physics
  - electronics and electrical engineering
  - computers and control
  - information technology

Search INSPEC with COMPENDEX, PHYSICS BRIEFS, MEET, NTIS and CAS ONLINE!

STN® INTERNATIONAL
The Scientific & Technical Information Network

2540 Olentangy River Road
Box 02228
Columbus, Ohio 43202 USA

Postfach 2465, D-7500
Karlsruhe 1
Federal Republic of Germany

Gakkai Center Building
2-4-16 Yayoi, Bunkyo-ku
Tokyo 113, Japan

mate change role seriously. Most of its research work is being done in its program planning and evaluation office, and less than a dozen staff persons are working full time on it. However, with the extra $5.6 million given to it by Congress to pursue risk assessment and risk management studies of global warming, the agency is ready to go.

"The actors are in place," says Thomas, "and with the additional money and resources we just got, we're going to see EPA in the course of this year not only better coordinated but with a better focus on its effects work. Some of that already has come out of EPA—like our sea-level rise study. We asked what effect [climate warming] would have on coastal wetlands. We found that the effects could be pretty dramatic with fairly small sea-level rises. We think effects work is important because it is a frame of reference for us to consider the impact environmentally in this issue and frames the kind of options a policy maker may want to consider."

EPA's big difficulty, says Thomas, is in the connection between CFCs and the greenhouse effect. "If you try to relate CFC regulations to greenhouse, you may have to make more stringent decisions," he explains. "We need to look at whether we want to include both effects [ozone depletion and climate warming] and set up a time frame for reviewing them over the next couple of years. Right now we don't know how we're going to fold them into the CFC issue. But greenhouse is going to be a factor in this."

EPA will step up its review of the science and keep up to date on findings, Thomas says. He believes a lot more research is needed, especially on the effects of warming. "This leads us to ask what kind of adaptation will be required if there's warming in certain parts of the world, what steps might be needed to reverse it. Some of that [research] is going to be done here [at EPA]." Still, he adds, "A lot of work around the world needs to be coordinated, and UNEP is a good center for much of that coordination.

"But collaboration is important among EPA, DOE, and the rest of the agencies. We need to be sure we can participate actively in framing some of the policy questions that must go to the science agencies. I realize there is some debate over whether you should do effects work before you are fully convinced you have an effect to deal with. But I see the whole process going along parallel sets of tracks."

C&EN staff photos

Merrell: tie science to policy studies

Plus tracks lining the tracks. "The key to it all," says NSF's assistant director for geosciences William Merrell, "is to be sure we tie the results from projects in the earth and atmospheric sciences to policy studies as rapidly as we can."

Where things are headed

Everyone involved with global change can agree on one thing: Industrialization is changing the physical atmosphere around Earth and thus every living thing on it. Research is needed to understand those changes as the gases build, converge, and interact. Policy choices will have to be made—perhaps with increasing frequency. So policy work will have to proceed in the face of scientific uncertainties.

That is what a veteran participant in international science and its policies underscored at a meeting earlier this month at Columbia University. He is Thomas Malone, formerly foreign secretary at NAS, official in the International Council of Scientific Unions, and now a professor at St. Joseph's College in Philadelphia.

"The essence of all of this," said

Thomas: better focus on effects work

Hecht: adapt one way or another

Malone, "is that the life portion and the physical portion of these problems are one integrated system. And this poses a tremendous challenge to the life sciences and the physical sciences to get together in a way that's never been accomplished before."

"It is not time to begin policy decisions," Malone added. "But it is time to lay the intellectual foundation for them. We have to do risk assessments. The kind of extreme effects EPA is identifying is precisely what should be done. It's not whether the global temperatures will rise 2 to 4°. It's what is the chance of an extreme event happening. It's the small chance-large consequence that we should be addressing."

Malone suggested that politicians should be brought into what amounts to policy games so they can be given a deeper understanding of the scientific uncertainties. Such games, involving what he called "surprise-rich scenarios," could supply political officials with insight into the consequences of their political decisions. He said the games should begin immediately.

EPA's Thomas agrees that a whole new era has arrived in environmental regulation and the policies needed to carry it out. "The interaction between us and other countries is more and more a direction we're taking," he says. "We're going

OUR PHARMACEUTICAL INTERMEDIATES

SNPE + $COCl_2$ =

NEW $RCHOCOCl$

ETHYL CHLOROFORMATE
DIETHYL CARBONATE
DiMETHYL CARBONATE
DIPHENYL CARBONATE
PIVALOYL CHLORIDE
TRICHLOROETHYL CHLOROFORMATE

CUSTOM PHOSGENATIONS

CHLORO -ALKYL-CHLOROFORMATES
α-CHLORO-ETHYL-CHLOROFORMATE ACE-Cl
α-CHLORO-ETHYL-ETHYL-CARBONATE

Today, based on its own research, SNPE makes available
NEW PHOSGENE DERIVATIVES for applications like:
- N-DEALKYLATION OF TERTIARY AMINES
- OH- AND NH_2 GROUP PROTECTION
- SYNTHESIS OF ANTIBIOTIC INTERMEDIATES
- PROTECTION AND ACTIVATION IN PEPTIDE SYNTHESIS

One of the few phosgene specialists, SNPE offers a comprehensive range of services in custom phosgenations and related reactions, from contract research to pilot plant scale or industrial manufacturing upon request.
Please ask for our literature or contact:
SNPE Inc. 103 Carnegie Center, Road One, Princeton NJ 08540 USA
Tlx: 132056 - Tel.: (609) 987.94.24
SNPE Dpt Chimie - 12, quai Henry IV, 75181 PARIS cedex 04 FRANCE.
Tlx: 220380 F - Tel.: 1.48.04.66.66.

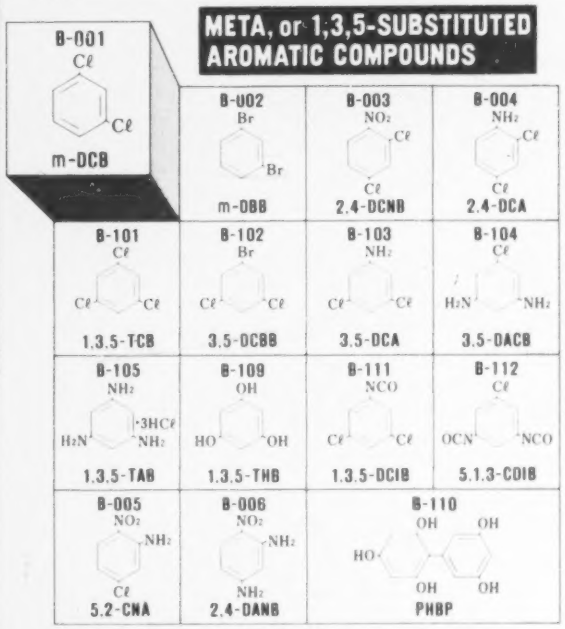
Name: _____
Function: _____
Company: _____
_____
Address: _____
_____
_____

CEN/24.11

SNPE

Organic Intermediates through Ishihara Sangyo's Advanced Technology:

META, or 1,3,5-SUBSTITUTED AROMATIC COMPOUNDS



Through the expertise and experience accumulated in the synthesis of agrochemicals over many years, ISHIHARA SANGYO has invented and developed effective organic synthesis technology. We wish to make the best use of our processes by solving problems that may occur in the synthesis of your products. Even if your exact compound is not listed above, please contact us with your specific need.

ISHIHARA SANGYO KAISHA, LTD.
10-30, Fujimi 2-Chome, Chiyoda-ku, Tokyo, Japan. Telex 2324306 ISK J
ISK (EUROPE) S.A. 33-31 Rue Montoyer, Box 8 1040 Bruxelles
Tel (02)512-54-50-512-72-78 Telex 23362 ITDD B
ISHIHARA CORPORATION (U.S.A.) Transamerica Pyramid 41st Floor 600 Montgomery Street, San Francisco, Ca 94111
Tel 415-421-8207 Telex 278010 ICUSA UR

HYDROGENATIONS . . . have them your way

- **CUSTOM . . . in our plant**
  Hexcel's modern production facilities are designed to provide custom hydrogenation in commercial quantities to exactly suit your requirements. Capabilities range from nominal pressures to 4,700 psi. Top quality and on-time performance is guaranteed.
- **VITRIDE® . . . in your plant**
  Vitride $NaAlH_2(OCH_2CH_2OCH_3)_2$ is a cost effective reducing agent that is proven safe for lab or production usage. Produced only by Hexcel, Vitride is non-pyrophoric, gives excellent yields, and allows higher reactor loads.

Either way, if you have hydrogenation requirements, check with Hexcel first. For complete information on our custom facilities or for technical data and samples of Vitride, call or write Hexcel Corporation, Chemical Products Division, 215 Centennial Street, Zeeland, MI 49464 (616) 772-2193 TLX 226 375.

HEXCEL chemical products

to see more and more of such issues. You can't take domestic regulatory action without affecting the economies of other countries."

Coordination is still the key, however. "Most so-called policy makers in Washington are pulling on disconnected levers," says Jesse Ausable, director of projects at the National Academy of Engineering. "We might wish that we could really change energy policy, but it's not so clear we can. All of us would agree that our bias could be to reduce emissions. But I just really wonder whether any sweep of policies that governments can enact will really make much difference. Even the best-meaning policies may be overwhelmed by factors of productivity growth, population growth, or the impossibility of developing solar or nuclear options. The question is how realistic these proposals are."

Maybe so, maybe not. Maybe the more basic question is whether, as Gore indicates, the prevention/adaptation options suggested are really too modest in the face of what lies ahead. The Ausables of the policy world believe the industrial countries possess the technologies to adapt. If so, it would follow that they also possess the technologies and policy capabilities to prevent.

The economic system has been adapting to the environmental era for two decades now. In that time the bugaboo of regulation stultifying growth of the gross national product has never been demonstrated. The two systems have shown they can live together—indeed, depend on one another. When a planet's life support system seems to be at stake, and when there does appear to be enough time to plan ahead, wouldn't economic caution amount to a silly luxury? □

Additional copies of this C&EN special issue will be available at $5.00 per copy. For 10 or more copies, $3.00 per copy. Send requests to: Distribution, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. On orders of $20 or less, please send check or money order with request.